Introduction to Engineering Seismology
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Module No # 04
Lecture No # 17
Concept of Earthquake Quantification – Magnitude

So vanakkam so we will continue our class on so concept of earthquake quantification ok. So this basically we discussed that the earthquake can be quantified 2 ways one is that intensity and the other one is magnitude. So if we recall the first part of the intensity discussion so we have discussed that the people are written a magnitude and then also they written a so moment magnitude. And also I told you that so the magnitude can be different for different wave type which is used.

So when this magnitude concept comes in to picture ok. So how, the magnitude quantification has been started the engineering seismology. And what we practice today is we are going to discuss in this class and followed by there is a so the energy released from the different earthquake and what type of magnitude how it is there all those things we have to discuss that in today's class.

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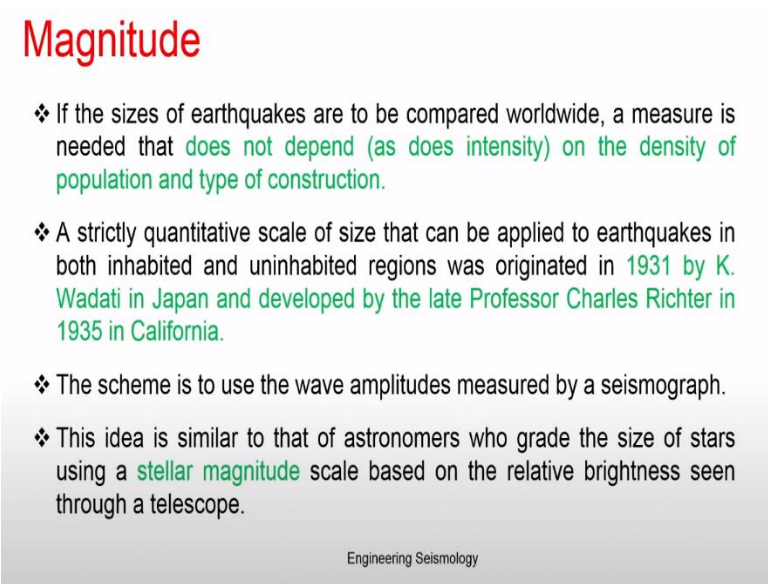

So the magnitude is basically the size of the earthquake that are to be compared worldwide to measure is needed that does not depend ok as does intensity on the density of the population and type of construction. So as we discussed that the intensity scale for example the intensity earthquake occurred in the forest region there is no people, there is no construction then the intensity scale is no where reported or it is 0 ok.

But actually the earthquakes are occurred. So such intensity is actually the function of number of people living their and number of houses and construction type in the region. So this kinds of things are biased. For example, the same earthquake occurring on Bangalore, the same earthquake occurring on Mysore, the same earthquake occurring somewhere north Karnataka reports village ok.

So we will have the different intensity because of the population and type of construction practiced in these places. Even, though the earthquake may release a same amount of the energy and the same magnitude. So these as been identified by the scientist and then they started thinking how to overcome this. A strictly quantitative scale of size that can be applied to earthquake in both inhabited and as well as the so uninhabited regions.

So, habited and inhabited regions so that it can be commonly give the same magnitude of value. So it was realized by the Wadati in Japan and then they developed by the late professor Charles Richter in 1935 in California ok. So the Charles Richter first thought about this and come up with the idea called magnitude. So this scheme is to use the wave amplitudes to measure in the seismograph ok. So we know that seismogram can record PS and L wave and R wave depends upon the seismogram.

So we try to use at and try to give you the magnitude. The idea is come from that, generally the astronomers what they do actually? They guess a size of a star ok by looking at its brightness ok. So how bright is? So the brighter star is assumed to be a bigger in scale ok. So that is what they did the similar kind of concept has been extended here to quantify the earthquake magnitude ok, the earthquake size in terms of magnitude.

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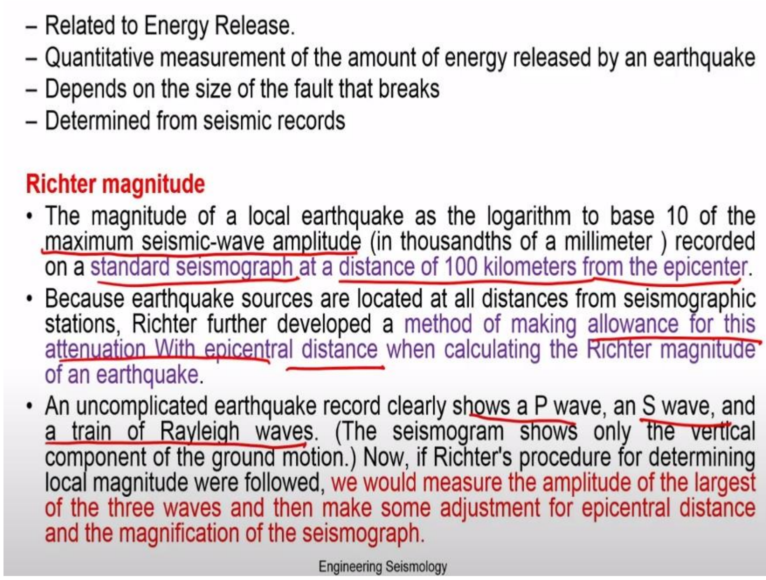

So these basically relate energy released by the earthquake because the wave form is a function of how much energy released ok. So the quantitative measurement amount of energy released by an earthquake will be reflected in the wave form what you see. It depends upon the size of the fault that breaks. So, as you know that the bigger fault breaks you will get a higher amplitude waves. So the then they determined from the seismic record. So that means if you want to estimate a magnitude you need to have the recorded earthquake data.

For intensity you no need to have any such kind of recorded. You need to have the damage observation physically by going to the sight or by getting the photos and try to understand. So these are all the 2 way you can estimate a intensity. So the Richter magnitude basically a magnitude of the local earthquake a the logarithmic to base 10 of the maximum seismic wave amplitude in thousandth millimeter recorded on a standard seismogram at a distance of 100 kilometer from the epicenter.

So here you should note that it should be maximum seismic wave amplitude ok in thousands of millimeter recorded at a standard seismogram and distance of 100 kilometer from the epicenter. So beyond this kind of distance you need to apply some kind of correction. Because the earthquakes sources are located at all the distances from seismogram station, Richter further developed method to making allowance for the basically attenuation of the wave with epicentral distance when calculation the Richter magnitude.

So uncomplicated earthquake record clearly shows the P wave and S wave and a train up of Rayleigh wave which is surfaced where the seismogram shows only the vertical component of the ground motion it can only show a one component. So now the Richter procedure; for determining the local magnitude were followed. We would measure the amplitude of the largest of the 3 wave then make some adjustment to the epicentral distance and then the magnification of the seismogram then you will get a magnitude.

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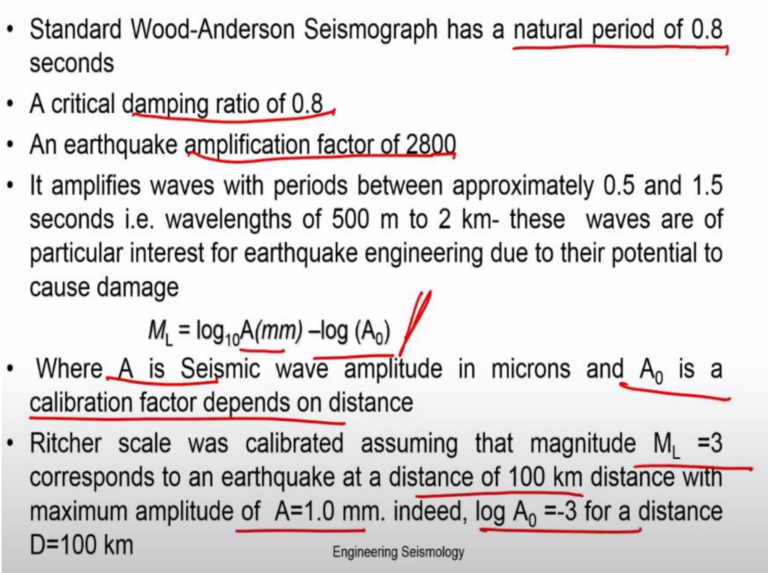

So that magnitude will be the Richter magnitude. So what was the Richter was used when he was arrived the magnitude basically used standard wood Anderson seismogram which was a so oldest seismogram which was developed. And then has been a natural period of so many second. These are all the very important the critical damping of the instrument is so much ok. The earthquake amplification factor is so much. How much the data is amplifies.

So it amplifies waves with period between he point 5 to 1.5 seconds the wavelength of 500 m to 2 km this waves are particular interest of the earthquake engineering due to their potential. So the ML is the function of log 10 A is the amplitude and then the A naught is a basically the calibration factor depends upon the distance ok. So base using this you can estimate what is the ML. The Richter scale was calibrated assuming that the magnitude of ML 3 correspond to the earthquake distance of 100 kilometer distance.

So with the maximum amplitude of mm indeed log A0 = -3 for a distance D equal to this one. So this is the wave where the bench marking has been done at initially by the Richter which has been used for arrive the Richter magnitude.

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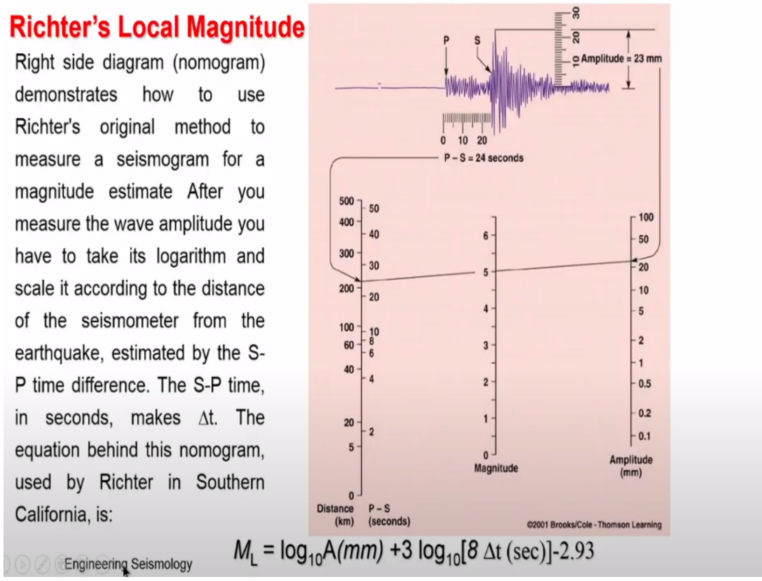

So how it works? You can see a typical waveform record of the particular earthquake okay. So this earthquake you can see ok. So you can basically so you can see the P wave and the S wave then followed by surface wave. So this particular location the P and S waves are very predominant when compare to the surface wave. So as per the Richter definition he says that maximum of this 3 amplitude you can see that maximum can be obtained from this particular place.

So you know what is the amplitude in the mm scale? So which; is basically this value ok since you know the P wave and S wave arrival so you can also get what is the time difference. This time difference as you told you that it gives you the how the earthquake epicenter is from your station record in terms of degree and you can multiply with the 1 1 0 kilometer per degree you can get a what is the distance.

You can see the P and S wave difference and their distance this ok. So by connecting these 2 you can connect this you will get a magnitude or you can use the equation where you get a magnitude. So finally based on this kind of explanation so the magnitude ML can be estimated using this functional form ok. So, where the amplitude of earthquake goes and the time difference and the distances also accounted with some kind of practice.

So you can see that it is in the log of 10. So the log of 10 means that the earthquake magnitude of 6 ok is 10 times larger than the earthquake magnitude of 5 ok. So the earthquake magnitude of 6.2 is actually 20 times larger than the magnitude of earthquake magnitude of sorry earthquake magnitude of 6.2 is actually 2 times larger than the magnitude of earthquake 6 ok. So 0.2 it is but 2 times so the 7 means it is 10 times. So that is what the log base 10 here indicates.

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Comparison to the Richter Scale and MMI

Earthquake	Death Toll	Richter Magnitude	Mercalli intensity
Tangshan earthquake (1976)	250,000	7.8-8.2	XI [4]
Loma Prieta earthquake (1989)	63	6.9	IX [5]
Kobe earthquake (1995)	6,434	6.8	X-XI [4]
Haiti earthquake (2010)	316,000	7.0	X
Christchurch earthquake (2011)	166 (final count expected to be over 180)	6.3	XI
Tōhoku earthquake (2011)	5400 confirmed, 8000 reported missing (final count expected to be over 10000). Totals include tsunami.	9.0	XI [6]

Richter Magnitude	Typical Maximum Modified Mercalli Intensity
1.0 - 3.0	I
3.0 - 3.9	II - III
4.0 - 4.9	IV - V
5.0 - 5.9	VI - VII
6.0 - 6.9	VII - IX
7.0+	VIII or higher

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So this is how the people started quantifying the earthquake based on the recorded data. You can see this is actually a typical earthquake and death toll and the Richter magnitude estimation and the Mercalli intensity. You can see that the intensity of Tangshan reported for the 250,000 people and then in 2010 it was reported 316,000 people ok. So even though it is a function of the damage but you can see the difference.

So this kind of ambiguity is now can be minimized when you have the quantified way of your seismic signal and which is further used for the getting this one. So you can see the 1 to 1 comparison between the Richter magnitude and typical maximum Mercalli intensity scale you can see how much it is coming ok. So this is the typical comparison of from the past earthquake.

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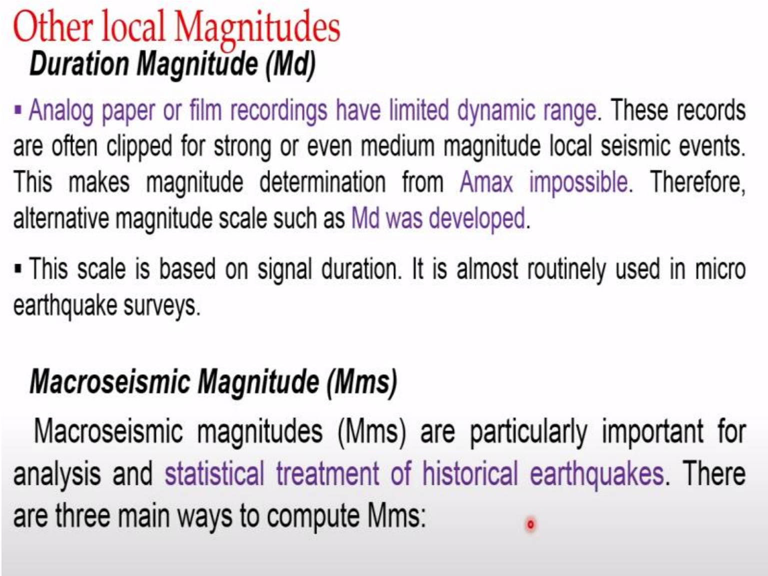

So other than Richter there is another magnitude developed which is also called local magnitude. Why it is local magnitude means? You can use generally the seismic record in the regional network will have the P and S wave as a major component ok. So those kinds of local data are been useful for original network data. That is why it is called as a regional magnitude. So the analog paper or film recordings have limited dynamic range.

So this record often clipped for the strong or even medium magnitude local events. It makes magnitude determination from the Amax impossible. So when you use a analog paper and all those day what happen due to the paper limitation and all you do not sometime record a highest peak which is happening in the site. So those cases using of those kinds of Amax for the local magnitude determination is problem.

So they come up with the alternate magnitude that is called as a MD. So the MD is basically duration magnitude it is based on the signal duration it is almost routinely used in the micro earthquake survey ok. So it is called as a MD. So another one; is used as a macro seismic magnitude. So which is a M and ms are particularly important for the analysis and statistical treatment of the historical earthquake data.

So three are the 3 main ways to compute the MMs are available. But these are all the scale only used at a selected place not universally accepted only the ML magnitude is universally accepted many people used. So now you know that why the Richter intensity or Richter magnitude is reported. So it has to be told the local magnitude or Richter magnitude. There is no quantification part Richter intensity or intensity in the Richter scalar those are all basically wrong description of the earthquake size.

So here we have seen that when there was a deep and far away earthquake ok so the local earthquake you will get a P and S wave dominant. If there is deep and far away earthquake you will not get P and S wave as a dominant measurement in the same seismic station. So those places basically they need to go for the alternate way of magnitude estimation where the concept of tele-seismic magnitudes, are come into picture ok.

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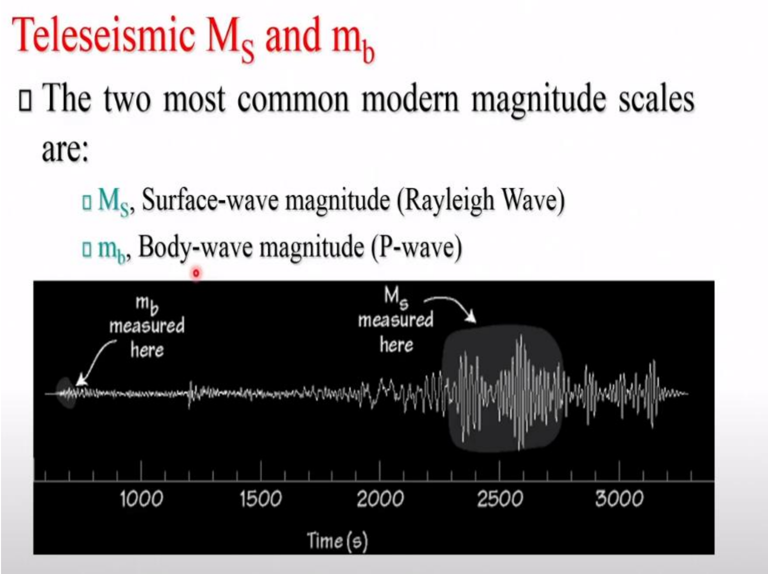

So there are 2 tele-seismic means the waves are traveling from the very far distance like body wave and a surface wave. So you can see the typical time lap and what was the surface wave arrival. You can see basically the surface wave arrival here see how much it is. So this is your mb. So some places where you will get mb as a predominant, some place you will get Ms as a predominant depends upon your location and where the earthquakes are occurring. That is what you have seen in the wave propagation.

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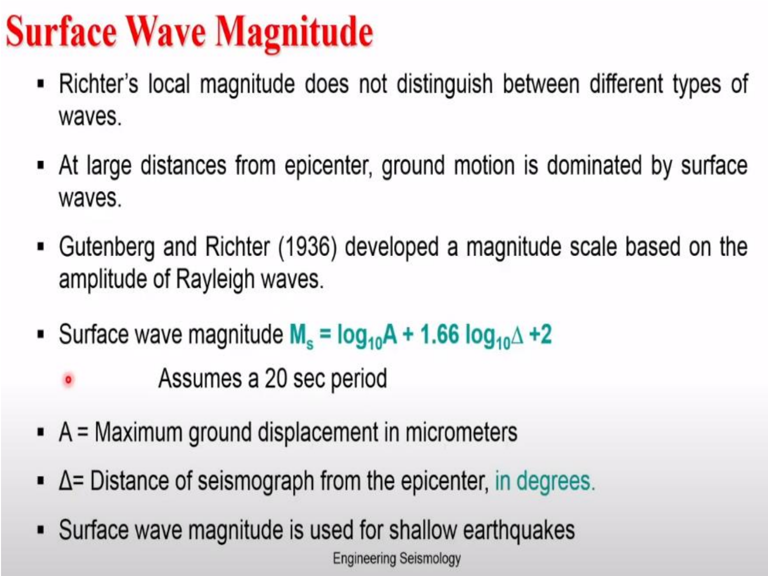

So the surface magnitude basically which uses a surface wave of the earthquake record. So the Richter local magnitude does not distinguish between the different types of waves. At large distances from the epicenter ground motion dominated by surface waves. The Gutenberg and Richter ok it is basically the student of Richter in 1939 develop a magnitude scale based on the amplitude rally wave. The surface wave Ms = log A + 1.66 log 10 delta +2 assumes that 20 second period.

A maximum ground displacement in micrometer. Delta is the distance of seismogram from the epicenter in degree. Surface wave magnitude is used for the shallow earthquakes ok. So this is a estimated from the surface wave record of the particular place.

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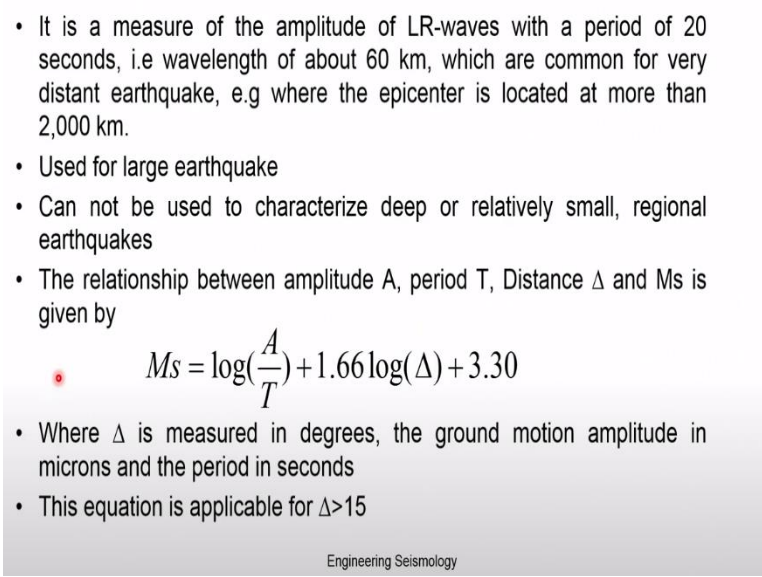

So it is measure of the amplitude LR waves basically the rally wave for the 20 seconds wave length is above 60 kilometer which are commonly very distance earthquake and where the epicenter is located more than 2000 kilometer. So used for the larger earthquake cannot be used for characterize deep and relatively small and regional earthquake. The relation between the amplitude A and period T and distance Delta and Ms is given by this relation which can be used to estimate a magnitude of the particular earthquake using the surface wave.

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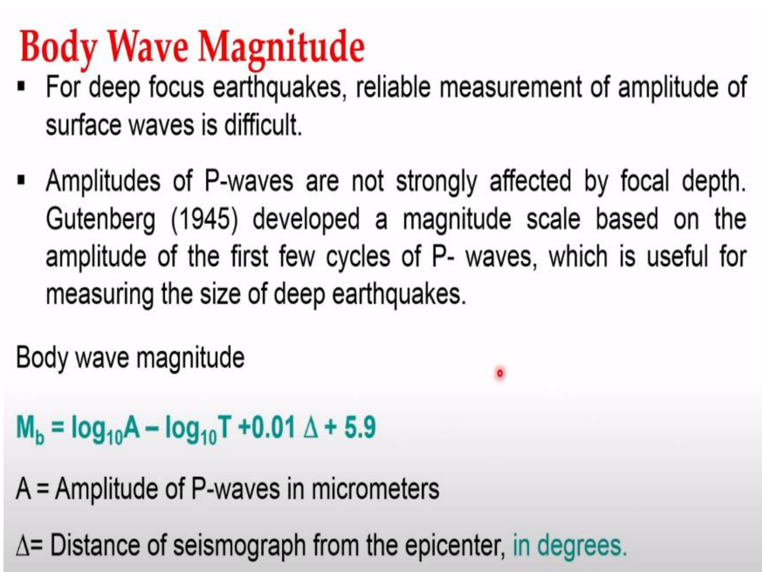

So the next is body wave magnitude. So they say that it is a basically estimated from the using body wave amplitude. So as we have seen that the amplitude of P wave are not strongly affected by the focal depth. The Gutenberg developed a magnitude scale based on the amplitude of the first few second of P waves which is useful for the measuring the size of deep earthquakes. So the body wave magnitude Mb is equal to this is the function they use so this is the amplitude and delta is the distance seismogram from the epicenter in degrees. And these are all the T and 5.9 as the constant.

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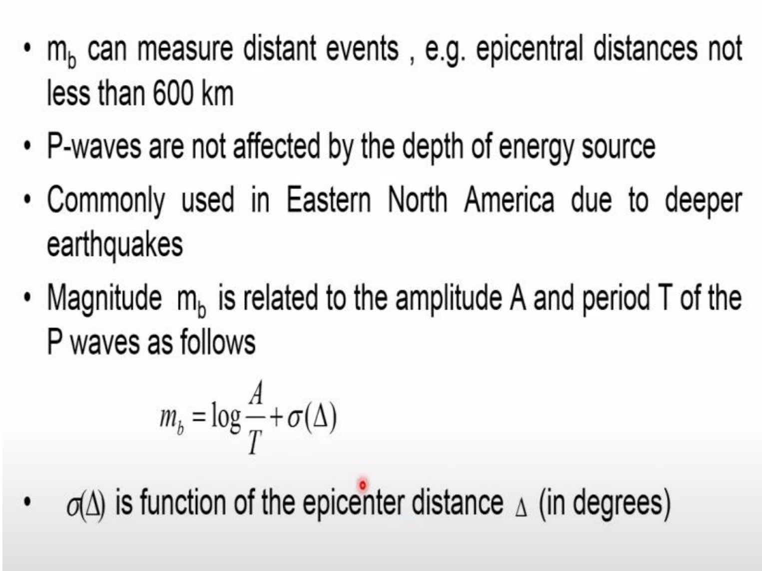

So using this you can get a mb can measure distance events epicenter distance are less than 600 kilogram. And the P waves are not affected by the depth of energy source. So commonly used in eastern north America due to deeper earthquake in that region. Magnitude Mb is related to the amplitude of A and period T and P waves as follows. So this is basically the relation between the A and T and delta D. So this will give you the mb magnitude.

So if you some earthquake if you, estimate see now we studied ML, mb and then MS. If we estimate all 3 for the same earthquake does it will be similar or different. Obviously it may not be similar as this is consider the wave amplitude depends upon the location of the place so you will get a shadow zone and non-shadow zone and then wave amplitude as a greater or smaller ok. So that is what it will give you. So this has been noticed by the scientist why the scale or not same ok.

For example the Turkey earthquake MS = 7.8, mb = 6.3 ok. So then the Taiwan MS = 7.7 and mb = 6.2. The distance correction factor for amplitude depends on the geology and deep earthquake do not generate large surface waves. So MS biased low for medium earthquake. Some of the earthquake last longer than the other even though the peak amplitude is not a same.

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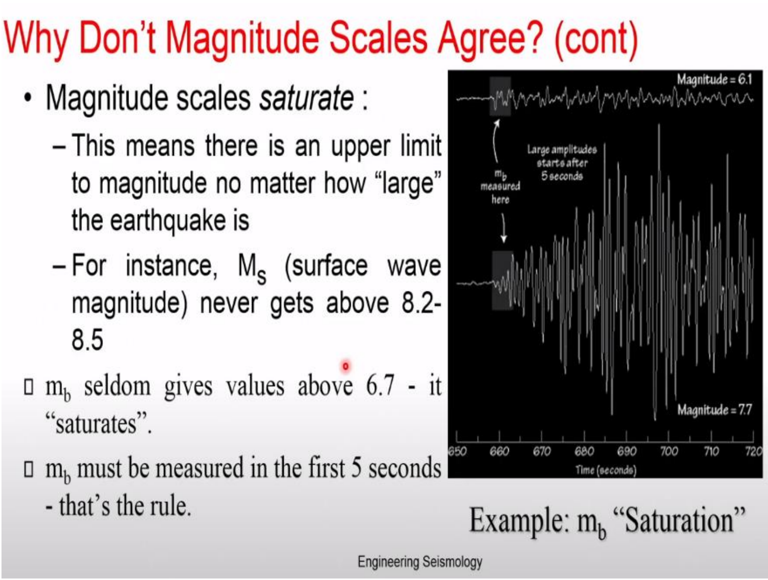

So this kind of phenomena where the magnitudes are not similar this because of the there is a saturation of the wave. So if you find the magnitude from the saturation this kind of magnitude which does not go beyond some limit is called as magnitude scale saturation. This means that there is a upper limit of the magnitude no matter how large the earthquake is ok if we consider ML, MS, mb kind of measurement.

For the instance MS surface wave magnitude never gets above 8.2. So mb seldom gives value of 6.7 in saturation b must be measure in the first 5 second of the rule. So this is the typical seismogram where you can see basically the mb measure here and then followed by the MS and as well as the surface wave magnitude using this data you can estimate a your this one.

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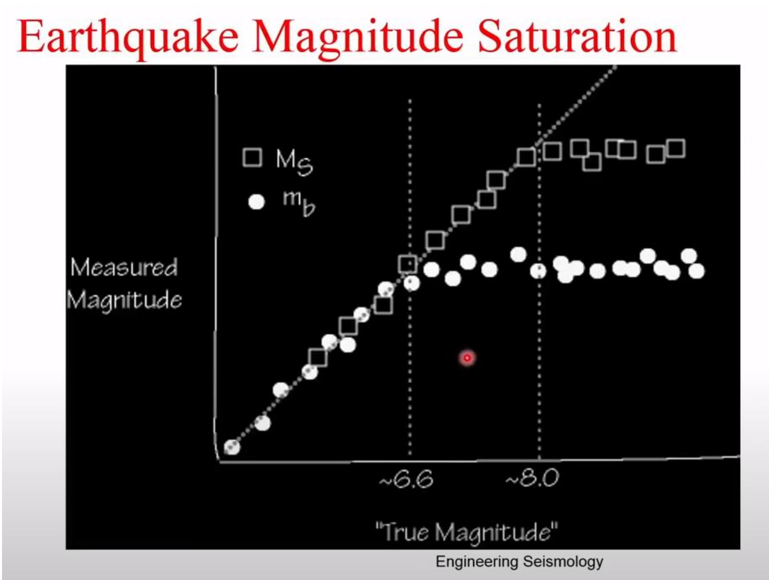

So if you plot the magnitude versus the measured data. You can see that the mb saturate at the value of 6.7. Similarly the MS saturate at a magnitude of 8. So beyond 8 you will get a same MS irrespective of the side distance and the side condition and wave what you record because that is the problem. So similarly 6.7 also for the same kind of issues we can expert in the magnitude.

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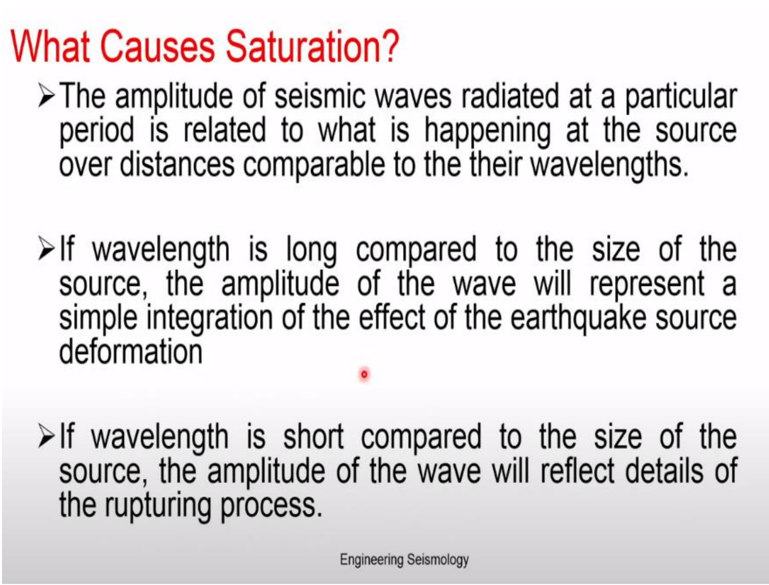

So this kind of phenomena after some value the magnitude is constant that kind of phenomena is called as a magnitude saturation which is called as magnitude saturation. That means up to some extend the value keep increasing beyond some that particular extent the magnitude remains constant irrespective of your amplitude and time. So, why the magnitude saturation happens? So the amplitude of the seismic waves radiate at a particular period is related to what happening to the source over a distance comparable to the wavelet.

If, the wavelet is long compared to the size of the source the amplitude of the wave will express simple integration of the effect of the earthquake source deformation. If the wavelength is short and compared to the size of the source the amplitude of the wave will reflect a detail of the rupturing process.

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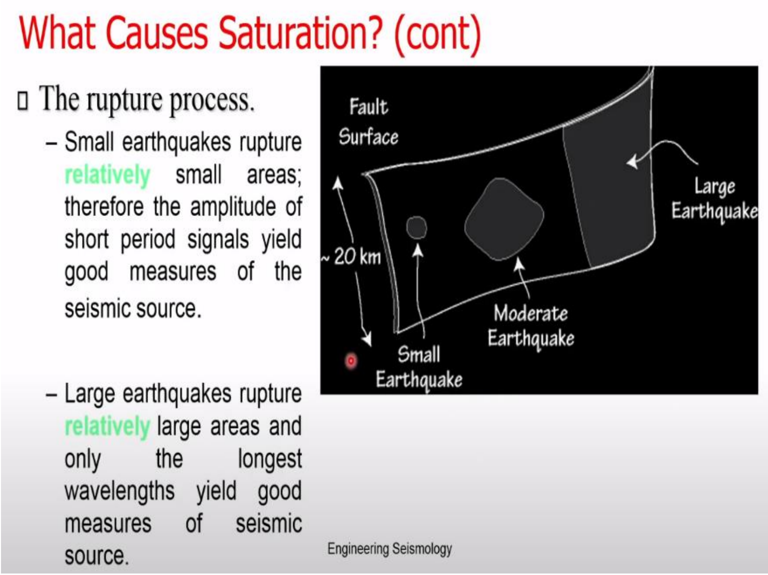

So these are all the reasons why the saturation is taking place. So in general the small earthquake for rupture relatively small area therefore the amplitude of short period signal need to be good yield a good measurement of the seismic source. So the large earthquake rupture; relatively large area where only the largest wavelength yield a good measures of seismic source. So when you measure a estimate a seismic magnitude you should be aware all this information which will help you to estimate a reliable magnitude for your sight and earthquake that will be so does not vary with respect to the time of the scale.

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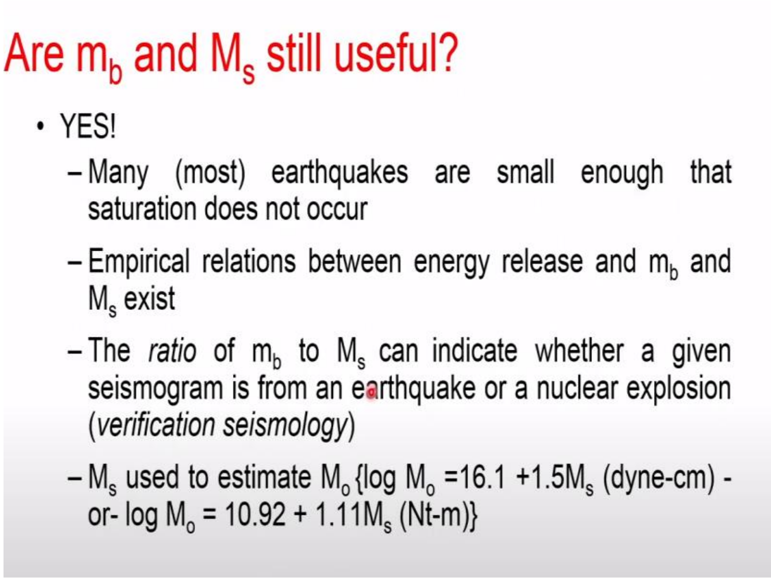

So but still this mb and MS are useful yes. Why because mini are most of the earthquake is small enough the saturation does not occur. You have seen that 6.7 for the mb and 8 for the MS. So if you have the less than that your magnitude will remains similar there is no kind of saturation or quarantine is required. So the empirical relation between the energy released and mb and Ms exist. So the most earthquakes are small enough which can be measure in this to scale.

And the empirical relation between mb and MS is exists. The ratio of mb to MS can be indicate whether the given seismogram is from an earthquake or nuclear explosion. So you can differentiate this is a artificially created seismic signal such as a blasting or nuclear explosion or this seismogram recorded data. So such kind of things can be arrived when you have the MS and mb.

So and also the MS will be used to estimate a energy from the earthquake because there is direct correlation between the MS and the M energy in the literature. So these are all the application where mb and MS still are useful.

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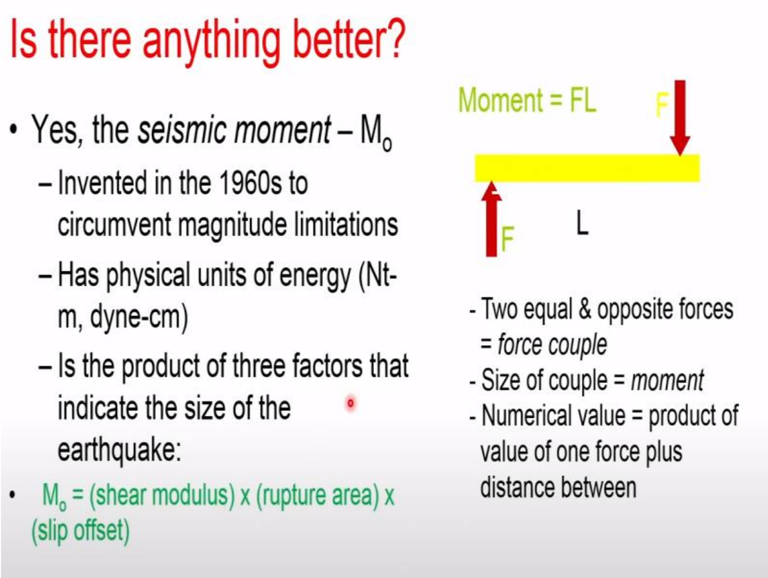

So anything better which can record the earthquake? Yes the scientists are gone through this one and try to update and come up with a new concept of magnitude which is based on the fault moment at a particular place. So the seismic moment which is called as a M naught so invented in 1960 to circumvent magnitude limitation as a physical unit of energy like in newton dyne centimeter or newton meter. This is a product of 3 factors that indicate size of the earthquake.

So the moment at particular place is equal to the stiffness, and rupture area and slip offset. So basically this is your fault so due to the up and down force. So you can get a moment. So which is the function of your shear modulus, so with this the function of material shear; modulus ok. Then the how much the breaks and ruptures and what is the offset it create or sleep so if you knowing this one can estimate what is the seismic moment M. So if you know the seismic moment you can estimate a moment magnitude ok.

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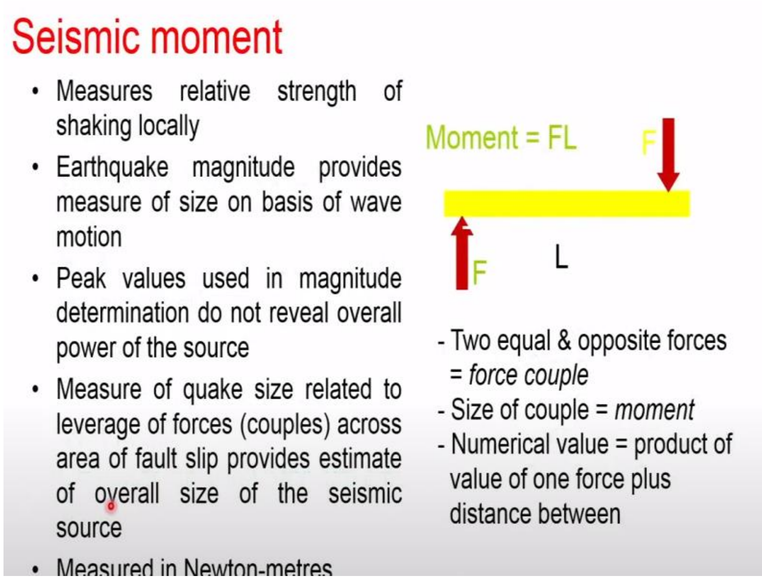

The seismic moment is basically the measure relative length of the shaking locally. The earthquake magnitudes provide measure of size on bias of the wave motion. The peak values used in the magnitude determination do not reveal overall power of the source. The measure of quake size related to leverage forces couples across the fault slip provides estimate overall size of that will be estimated that is called as a FL is called as a seismic moment.

That moment is used to estimate to a magnitude. That magnitude is called as a moment magnitude.

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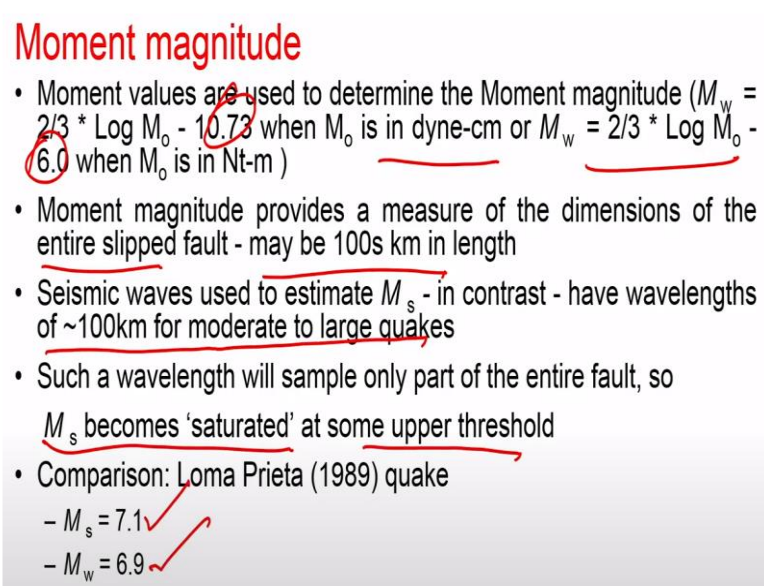

So the moment value are used to determine the moment magnitude the MW = two third of log M naught -10.73 and M naught is dyne for you can see that it is dyne for the dyne centimeter. So if you use some other unit basically you will be getting a different equation. You can see these constants are changing. You can see here and you can see here ok. This is the newton meter that is on the dyne centimeter.

So the moment magnitudes provide measure of the dimension of the entire slip of the fault and may be 100 seconds kilometer length. Seismic wave used to estimate Ms is in contrast have, the wavelength of close to 100 kilometer for the moderate to large earthquake. Such a wavelength will sample only part of the entire fault. So Ms become a saturated and same upper threshold value. So by comparing the Lomo Prieta earthquake you can see the Ms is so much, Mw is so much ok.

So this is the difference we can estimate. But to measure the moment you need to know what is the; rupture length of the fault?

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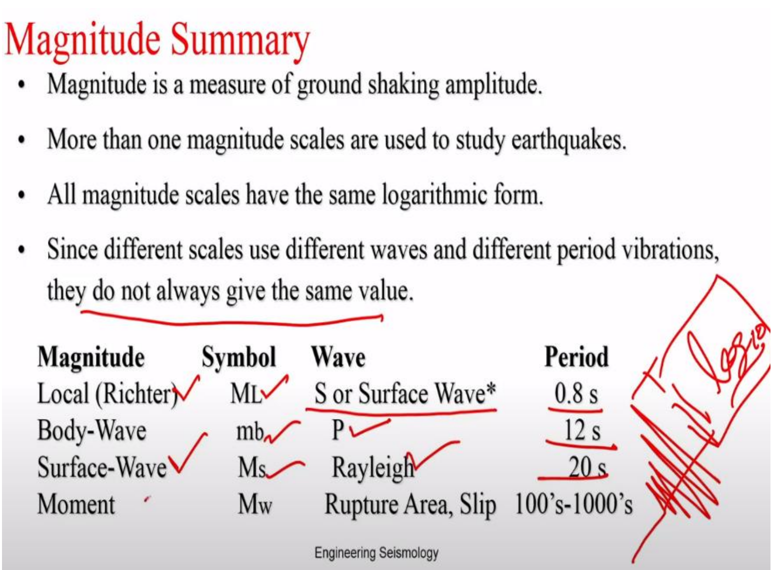

So the magnitude so overall whatever we discussed so we can see that the magnitude is measure up the ground shaking amplitude ok which is the function of basically how much the amplitude the earthquake has been reported like this ok. How much the amplitude is report that amplitude value is your magnitude let say it may be your P or it may be the S or may be the surface wave depends on.

So the more that one magnitude scale are generally used to quantify the earthquake depends upon the development taken place. All the magnitude scales have the same kind of algorithm form. If we observe the equation all of them is the function of log 10 base. So which indicate that one magnitude like 5, 6 is even though number wise it is only 1 increment but if you say earthquake magnitude 5 and 6 ok which is 10 times larger and smaller.

For example the 4 magnitude is actually 100 times smaller than the 6 magnitude and a similarly 10 times larger than the 3 magnitude of 4. So such kind of amplitude log difference has been in that is why it is used to a log 10 base as a magnitude estimation. So since difference scales are used in different way different period of vibration they do not always give a same value which we have seen in the some of the example.

So in summary the local magnitudes develop by a Richter which is indicated by ML which is generally use as S or surface wave. The maximum component of these 3 wave for a period of so much. The body wave indicated by the mb and uses only the P wave and only the period they use was 12 second. The surface Ms and the Rayleigh wave and it is used so much. The moment magnitude Mw rupture area and slip this is a period the data what they are using for a assessing that ok.

So among this magnitude basically the moment magnitude is more reliable way of getting the earthquake measurement.

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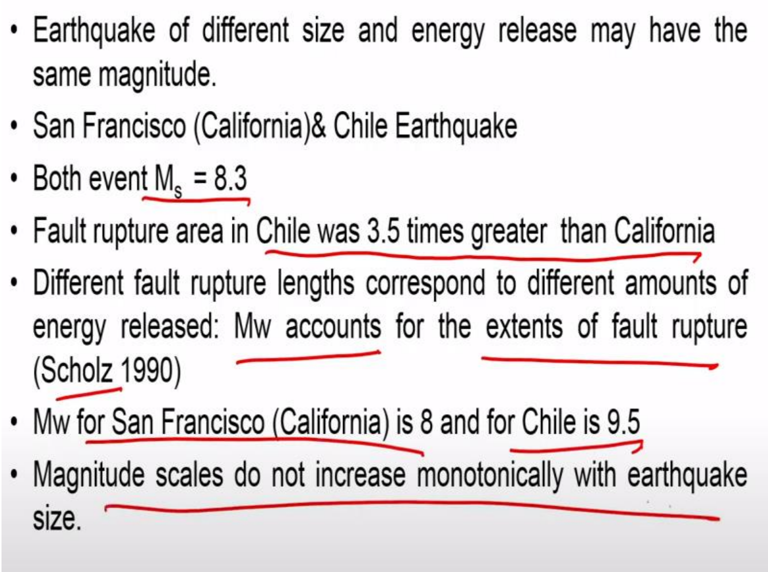

So the earthquake different size and energy releases may have the same earthquake magnitude. So the San Francisco, California and a Chile earthquake has been taken and both event basically measured MS of 8.3. The fault rupture area of Chile earthquake is actually 3.5 times greater than California earthquake. So, different fault rupture length, correspond to the different amount of energy release.

So the Mw accounts extents of the fault rupture so the Mw for the San Francisco earthquake is actually 8 and Chile is 9.5. The magnitude scales do not increase monotonically with earthquake size ok that was a observation from this you can say. So the Mw is the most reliable scale so as on today they use.

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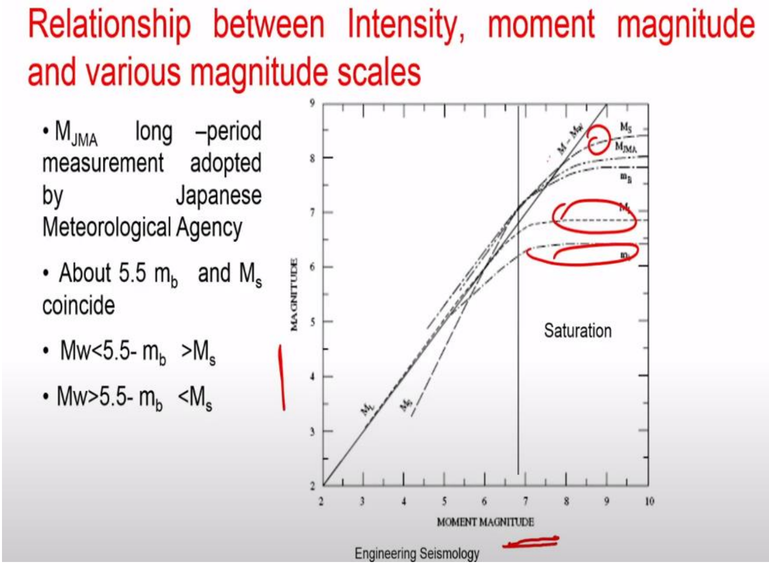

So since it was this one there was is a old all the old scales are being converted and there is a conversion for that. So this is the different magnitude moment magnitude this is the different magnitude. You can see here the magnitude of ML up to magnitude of 7 it is no saturation take place. After that there is a saturation. So Mb saturates at a 6.7 you can see here ok. So the Mjb magnitude Japan so long period measurement earthquake and you can see here this is the M - Ms ok this one. And M moment magnitude does not saturate with the earthquake. So the moment magnitude can be find out for the any earthquake.

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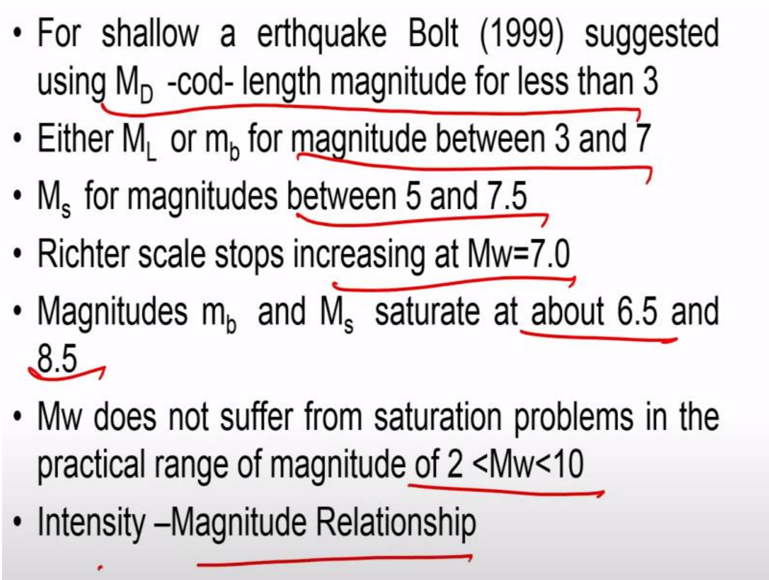

For the shallow crystal earthquake Bolt suggested that MD and coda length magnitude less than 3 can be used. Shallow crystal either ML or mb for the magnitude between the 3 and 7 will be fine. So the MS for the magnitude between 5 to 7.5. Richter scale stops increasing at magnitude 7. Magnitude at mb and MS saturate at about 6.5 and 8.5.

So Mw does not suffer from saturation so the problem in the practical range is magnitude 2 to 10 ok. The intensity magnitude relations are available where you can convert intensity as a magnitude, magnitude as a intensity.

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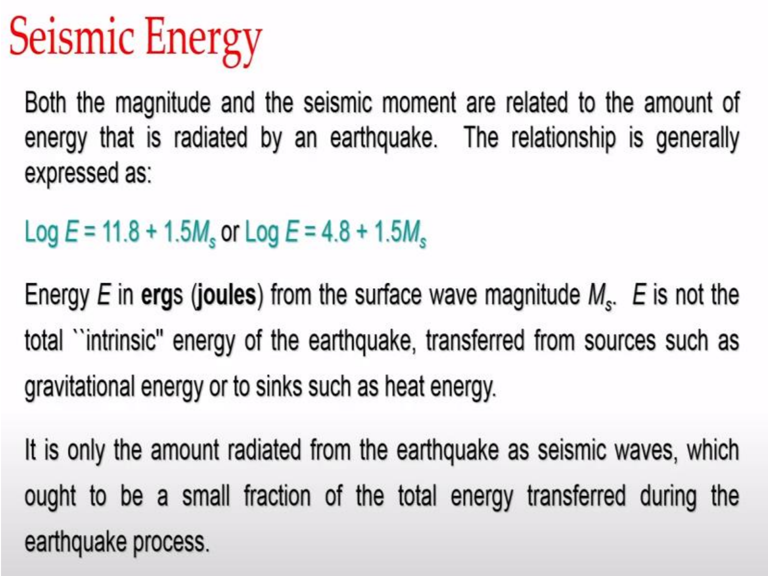

So those data's are really useful for the your so prediction of the earthquake hazard. So this is about the earthquake magnitude. So during the earthquake magnitude we are also discussed about a energy. So the energy means basically the amount of energy released due to the breaking of the fault. Both the magnitude and the seismic moment are related to the amount of energy that is radiates from the earthquake which you will discuss in the next class.

So today class we have seen about the magnitude and then different type of magnitude scale how you can quantify the magnitude. So we have noticed that all the magnitude is the function of log 10 waves. So that means 1 magnitude is so greater than 10 times ok. So smaller or larger depends upon which number it comes ok. So that is what we have seen so this energy is a function of the wave what you are seeing and how to estimate energy and what are the energy content in the previous earthquakes are reported.

What are the nuclear explosion are taking place and how that energy was there will discuss in the next class. So with this I thank you for watching this video. So we will meet in the next class. Thank you very much.